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EFFICIENT GROUP ACCEPTANCE PLANS BASED ON TOTAL NUMBERS OF FAILURES FOR GENERALIZED EXPONENTIAL DISTRIBUTED PRODUCTS

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ABSTRACT
In this manuscript, efficient group plan based on total numbers of failures is designed when the lifetime of the product follows the generalized exponential distribution. Group plan are applicable when the multiple items can be installed in a single testes. The optimal plan parameters such as number of groups and acceptance number are determined by satisfying both the consumer's risk and producer's risk at a specified percentiles ratio, termination time and the number of testers. The advantages of proposed plan over the existing plans are discussed. The tables are constructed and results are discussed with examples.

KEYWORDS: Group acceptance sampling plan; Generalized exponential distribution, consumer's risk, producer's risk, Truncated life test.

INTRODUCTION

To improve the quality of the product to compete with other companies in National or International levels is main aim of the producers today. The high quality products definitely protect producers and increase the level of consumer's confidence on his products. On the other hand, consumer wants his protection to avoid that product which is not good quality. So, the acceptance of the lot of the product and producer and consumer protection is basic questions in market. The acceptance sampling schemes provides the answers of this type of questions and suggests the optimal sample size and acceptance number that should be selected at the time of the inspection. Acceptance sampling plans have several advantages in the area of reliability including to provide optimal sample size, acceptance number, probability of acceptance, minimum percentile ratio, minimum experiment time to save cost of the inspection, time of the inspection and provide the protection to producer and consumer. It should be noted that whatever the type of the acceptance sampling plans producer's risk and consumer's risk are always attached with these schemes. In ordinary single acceptance plan, single item is installed on a tester that needs more time and efforts to inspect product. On the other hand, The group sampling plan that is implemented when the experimenter has the facility to install more than one item in a single testes. For more details about group sampling plans, reader may refer to Aslam and Jun (2009). The group acceptance is the generalization of the ordinary single acceptance sampling plans. Recently, many authors developed ordinary and group acceptance sampling plans based on truncated life tests for various distributions including Epstein (1954), Goode and Kao (1961), Kantam and Rosaiah (1998), Fertig and Mann (1998), Kantam *et al*. (2001), Baklizi (2003), Rosaiah *et al*. (2006), Rosaiah and Kantam (2005), Jun *et al*. (2006), Tsai *et al*. (2006), Rosaiah et al. (2007), Aslam and Shahbaz (2007), Balakrishnan et al. (2007), Aslam and Jun (2010), Pascual and Meeker (1998), Vlcek *et al*. (2003), Jun *et al*. (2006), Aslam and Jun (2009), Rao (2009,2010) . developed the single acceptance sampling plan based on the generalized exponential distribution. More recently, Shoaib *et al*. (2011) group plan for Birnbaum- Saunders distribution percentiles.

Gupta and Kundu (1999, 2007) originally developed the generalized exponential distribution that is wildly used in the area of reliability and acceptance sampling plans. According to them, the generalized exponential distribution is effectively used in some situations than the Weibull distribution and log normal distribution. Aslam *et al*. (2010, 2011) used the generalized exponential distribution to develop the ordinary acceptance sampling plans and group acceptance sampling plans. The group plan proposed by Aslam *et al*. (2011) based on the acceptance criteria that reject the lot if in any group the numbers of failures are more than the specified acceptance number. So, there is need to proposed a group plan based on the total number of failures from all the groups to accept or reject the submitted product. Therefore, the main purpose of this paper is to develop the group acceptance sampling plan based on total numbers failures for generalized exponential distribution using median as quality parameter. This distribution has following probability density function (pdf) and cumulative distribution function (cdf)

$$f(t) = \frac{\delta}{\lambda} e^{-t/\lambda} \left(1 - e^{-t/\lambda}\right), \qquad t > 0, \lambda > 0, \delta > 0 \tag{1}$$

$$F(t) = \left(1 - e^{-t/\lambda}\right)^{\delta}, \qquad t > 0 \tag{2}$$

Where $\lambda > 0$ is the scale parameter, $\delta > 0$ is the shape parameter. The median of generalized exponential distribution is given by:

$$m = -\lambda \ln\left(1 - (1/2)^{1/\delta}\right) \tag{3}$$

The rest of the paper is organized as follows: design of total failure group plan is given in section 2. Description of tables and example is given in Section 3. The advantages of the proposed plan over the existing plans are discussed in Section 4. Some concluding remarks are given in last section.

Designed Group Sampling Plan under Total Number of Failures

We are interested in developing a group sampling plan under the total number of failures scheme. This scheme is the improvement of the existing plan (Aslam and Jun (2009a, 2009b). In this plan assure that the median life of items in a lot (m, say) is greater than the specified median life (m_0, say). If $H_0 : m \geq m_0$, we will accept the lot at certain level of consumer's and producer's risks, otherwise we have to reject the lot. The designed group sampling plan under the total number of failures is stated below (Aslam *et al*. 2011):

1. Draw the random sample of size n from a lot, allocate r items to each of g groups (or testers) so that $n = rg$ and put them on test for the duration of t_0.
2. Accept the lot if the total number of failures from g groups is smaller than or equal to c. Truncate the test and reject the lot as soon as the total number of failures from g groups is larger than c before t_0.

The lot is accepted if the total number of failures /defectives from all groups is smaller than or equal to specified acceptance number c. So, the lot acceptance probability of the designed plan is given by:

$$L(p) = \sum_{i=0}^{c} \binom{rg}{i} p^i (1-p)^{rg-i}. \tag{4}$$

Where p is the probability that an item in a group fails before the termination time t_0. According to Aslam and Jun (2009) "It would be convenient to determine the termination time t_0 as a multiple of the specified median life m_0". That is, we will consider $t_0 = am_0$ for a constant a.

The generalized exponential distribution under the median lifetime is given by:

$$p = \left[1 - \exp\left(\frac{a\gamma}{m/m_0}\right)\right]^{\delta} \tag{5}$$

Where $\gamma = \ln\left[1 - (1/2)^{1/\delta}\right]$

The probability of rejecting a good lot is called the producer's risk α and the probability of accepting a defective lot is called the consumer's risk β. Group sampling plan under the median life to specified life m/m_0 is developed and find the minimum number of groups and acceptance number by satisfying the

following two inequalities based on the two point approach such that consumer's and producer's risks satisfied simultaneously.

$$L(p/m/m_0 = r_1) \leq \beta \tag{6}$$
$$L(p/m/m_0 = r_2) \geq 1-\alpha \tag{7}$$

Where r_1 and r_2 are the median ratios that will be specified at the consumer's and producer's risks, respectively. Let p be the failure probabilities corresponding to consumer's and producer's risks. The required number of groups can be determined through the following inequalities.

$$L(P_1) = \left(\sum_{i=0}^{c} \binom{rg}{i} p_1^{\,i} (1-p_1)^{rg-i} \right) \leq \beta \tag{8}$$
$$L(P_2) = \left(\sum_{i=0}^{c} \binom{rg}{i} p_2^{\,i} (1-p_2)^{rg-i} \right) \geq 1-\alpha \tag{9}$$

Description of Tables and examples

Tables 4-6 show the minimum number of groups g and the acceptance number c required for the group acceptance sampling plan under the total failure according to various values of the consumer's risk $(\beta = 0.25, 0.10, 0.05, 0.01)$ when the true median lifetime equals the specified life and 5% of producer's risk when the true median $(m/m_0 = 2,4,6,8,10,12)$ times the specified life. Two level of group size $(r = 5,10)$ and two levels of termination time multiplier $(a = 0.5, 1.0)$. We consider different values of the δ to find the minimum sample size can be obtained, if needed, by $n = r \times g$.

These tables are constructed by using different values of the shape parameter of generalized exponential distribution for example $\delta = 2, \delta = 3, \delta = 4$ and find the designed parameter i.e. minimum number of group g and acceptance number c by using the total failure scheme. In Table4 we use the median lifetime with shape parameter $\delta = 2$ and find the minimum number of groups and acceptance number for example $(g, c, r, \beta, m/m_0) = (7,5,5,0.25,2)$. In Table 5 we use the median lifetime with shape parameter $\delta = 3$ and find the minimum number of groups and acceptance number for example $(g, c, r, \beta, m/m_0) = (4,1,5,0.25,4)$. In Table 6 we use the median lifetime with shape parameter $\delta = 4$ and find the minimum number of groups and acceptance number for example $(g, c, r, \beta, m/m_0) = (6,2,5,0.25,2)$.

Example

Suppose, for example, that the lifetime of an item under this manuscript is known to follow a generalized exponential distribution with the shape parameter $\delta = 2$. Suppose that it is desired to develop the group acceptance sampling under the total number of failures to assure that the median life is greater than 2000h through the experiment to be completed by 2000h using testers equipped five product each. Suppose that the consumer's risk is 10% when the true median is 2000h and the producer's risk is 5% when the true median is 4000h. Since $\delta = 2, \beta = 0.10, r = 5, a = 0.5, m/m_0 = 4,$ the minimum number of group and

acceptance number can be found as $g = 5, c = 2$ from Table 4. This indicates that a total of 25 items are needed and these five items will be allocated to each of five testers. We will accept the lot if no more than two failures occurs before 2000h from all groups, otherwise reject the lot.

Comparison

In this section explained the advantage of the proposed group acceptance sampling plan over the original group acceptance sampling plan Aslam and Jun (2009), two plans are compared on the basis of the required number of groups g .

Table 1: Comparison between proposed plan vs. existing plan when $\delta = 2, a = 0.5$

		$r = 5$		$r = 10$	
		Generalized exponential distribution		Generalized exponential distribution	
		Total failure plan	existing plan	Total failure plan	existing plan
β	m/m_0	g	g	g	g
0.25	2	7	170	4	10
	4	3	5	2	2
	6	3	5	2	2
0.10	2	11	281	6	57
	4	5	7	3	3
	6	4	7	2	3
0.05	2	15	366	8	73
	4	6	9	3	3
	6	5	9	3	3
0.01	2	20	3354	10	113
	4	8	68	4	11
	6	6	14	3	5

Table: 2 Comparison between proposed plan vs. existing plan when $\delta = 3, a = 0.5$

		$r = 5$		$r = 10$	
		Generalized exponential distribution		Generalized exponential distribution	
		Total failure plan	existing plan	Total failure plan	existing plan
β	m/m_0	g	g	g	g
0.25	2	7	42	4	6
	4	4	7	2	2
	6	2	2	1	1
0.10	2	8	69	4	10
	4	5	12	3	4
	6	3	3	2	2
0.05	2	11	89	7	45
	4	6	15	3	5
	6	4	4	2	2
0.01	2	18	1513	9	70
	4	8	23	4	7
	6	8	23	4	7

Table: 3 Comparison between proposed plan vs. existing plan when $\delta = 4, a = 0.5$

		$r = 5$		$r = 10$	
		Generalized exponential distribution		Generalized exponential distribution	
		Total failure plan	existing plan	Total failure plan	existing plan
β	m/m_0	g	g	g	g
0.25	2	6	10	3	3
	4	2	2	1	1
	6	2	2	1	1
0.10	2	8	126	4	17
	4	4	4	2	2
	6	4	4	2	2
0.05	2	12	164	6	22
	4	5	5	4	7
	6	5	5	3	3
0.01	2	17	252	9	33
	4	10	34	5	10
	6	7	7	4	4

In The Table1, the generalized exponential distribution provides the minimum number of groups in total failure plan as compared to existing plan by using the shape parameter $\delta = 2$. The number of groups of level 2 is very small in total failure plan as compared to existing plan. Table 2 and Table 3 also indicates that the generalized exponential distribution provides the minimum number of groups in total failure plan as compared to existing plan by using the shape parameter $\delta = 3, \delta = 4$ respectively. The number of groups of level 2 is also very small in total failure plan as compared to existing plan.

CONCLUSION

In this manuscript, we designed the Group acceptance sampling plan for generalized exponential distribution under the truncated lifetimes according to total failure plan. The required minimum number of groups and acceptance numbers are determined by using the two point approach. This manuscript only deals with the generalized exponential distribution to check the multiple numbers of items simultaneously by saving cost and time. This article shows that the proposed plan is better than the original plan (Aslam and Jun (2009)) because the number of groups is minimum as compared to original plan. This article also represented that the number of groups according to group size $r = 10$ is smaller as compared to group size $r = 5$ by using the generalized exponential distribution.

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Table 4: Minimum number of groups and acceptance number for the Total failure plan for the Generalized exponential distribution using median and $\delta = 2$

β	m/m_0	r=5						r=10					
		$a=0.5$			$a=1.0$			$a=0.5$			$a=1.0$		
		g	c	L(P2)	g	c	L(P2)	g	c	L(P2)	g	c	L(P2)
0.25	2	7	5	0.9673	4	7	0.9575	4	6	0.9803	2	7	0.9575
	4	3	1	0.9638	1	1	0.9576	2	2	0.9927	1	2	0.9718
	6	3	1	0.9913	1	1	0.9888	2	1	0.9848	1	1	0.9560
	8	3	1	0.9970	1	1	0.9961	2	1	0.9947	1	1	0.9834
	10	2	0	0.9651	1	1	0.9983	1	0	0.9651	1	1	0.9925
	12	2	0	0.9754	1	0	0.9536	1	0	0.9754	1	1	0.9962
0.10	2	11	7	0.9636	6	10	0.9637	6	8	0.9771	3	10	0.9637
	4	5	2	0.9863	2	2	0.9717	3	2	0.9776	1	2	0.9718
	6	4	1	09848	2	1	0.9551	2	1	0.9848	1	1	0.9560
	8	4	1	0.9947	2	1	0.9834	2	1	0.9947	1	1	0.9834
	10	2	0	0.9651	2	1	0.9925	1	0	0.9651	1	1	0.9925
	12	2	0	0.9754	1	0	0.9536	1	0	0.9754	1	1	0.9962
0.05	2	15	9	0.9644	6	10	0.9637	8	10	0.9768	3	10	0.9637
	4	6	2	0.9776	3	3	0.9826	3	2	0.9776	2	3	0.9531
	6	5	1	0.9767	2	1	0.9551	3	1	0.9673	1	1	0.9560
	8	5	1	0.9918	2	1	0.9834	3	1	0.9883	1	1	0.9834
	10	5	1	0.9963	2	1	0.9925	3	1	0.9948	1	1	0.9925
	12	3	0	0.9633	1	0	0.9536	2	0	0.9514	1	1	0.9962
0.01	2	20	11	0.9536	9	14	0.9619	10	11	0.9536	5	15	0.9529
	4	8	2	0.9529	4	3	0.9531	4	2	0.9529	2	3	0.9531
	6	6	1	0.9673	3	2	0.9861	3	1	0.9673	2	2	0.9704
	8	6	1	0.9883	3	1	0.9638	3	1	0.9883	2	2	0.9927
	10	6	1	0.9948	3	1	0.9833	3	1	0.9948	2	1	0.9711
	12	4	0	0.9514	3	1	0.9913	2	0	0.9514	2	1	0.9848

Table 5: Minimum number 0f groups and acceptance number for the Total failure plan for the Generalized exponential distribution using median and $\delta = 3$

β	m/m_0	r=5						r=10					
		$a = 0.5$			$a = 1.0$			$a = 0.5$			$a = 1.0$		
		g	c	L(P2)	g	c	L(P2)	g	c	L(P2)	g	c	L(P2)
0.25	2	7	3	0.9678	3	5	0.9755	4	3	0.9509	2	6	0.9671
	4	4	1	0.9942	1	1	0.9888	2	1	0.9942	1	1	0.9551
	6	2	0	0.9814	1	1	0.9985	1	0	0.9814	1	1	0.9935
	8	2	0	0.9917	1	0	0.9716	1	0	0.9917	1	1	0.9986
	10	2	0	0.9956	1	0	0.9845	1	0	0.9956	1	0	0.9693
	12	2	0	0.9974	1	0	0.9907	1	0	0.9974	1	0	0.9814
0.10	2	8	3	0.9509	4	6	0.9671	4	3	0.9509	2	6	0.9671
	4	5	1	0.9909	2	1	0.9551	3	1	0.9871	1	1	0.9551
	6	3	0	0.9723	2	1	0.9935	2	0	0.9632	1	1	0.9935
	8	3	0	0.9876	1	0	0.9716	2	0	0.9835	1	1	0.9986
	10	3	0	0.9935	1	0	0.9845	2	0	0.9913	1	0	0.9693
	12	3	0	0.9961	1	0	0.9907	2	0	0.9948	1	0	0.9814
0.05	2	11	4	0.9584	5	7	0.9607	7	5	0.9655	3	8	0.9559
	4	6	1	0.9871	2	1	0.9551	3	1	0.9871	1	1	0.9551
	6	4	0	0.9632	2	1	0.9935	2	0	0.9632	1	1	0.9935
	8	4	0	0.9835	1	0	0.9716	2	0	0.9835	1	1	0.9986
	10	4	0	0.9913	1	0	0.9845	2	0	0.9913	1	0	0.9693
	12	4	0	0.9948	1	0	0.9907	2	0	0.9948	1	0	0.9814
0.01	2	18	6	0.9629	6	8	0.9559	9	6	0.9629	3	8	0.9559
	4	8	1	0.9777	3	2	0.9861	4	1	0.9777	2	2	0.9695
	6	8	1	0.9974	3	1	0.9855	4	1	0.9974	2	1	0.9749
	8	6	0	0.9754	3	1	0.9967	3	0	0.9754	2	1	0.9942
	10	6	0	0.9869	2	0	0.9693	3	0	0.9869	1	0	0.9693
	12	6	0	0.9923	2	0	0.9814	3	0	0.9923	1	0	0.9814

Table 6: Minimum number 0f groups and acceptance number for the Total failure plan for the Generalized exponential distribution using median and $\delta = 4$

β	m/m_0	r=5						r=10					
		$a = 0.5$			$a = 1.0$			$a = 0.5$			$a = 1.0$		
		g	c	L(P2)	g	c	L(P2)	g	c	L(P2)	g	c	L(P2)
0.25	2	6	2	0.9825	2	3	0.9682	3	2	0.9825	1	3	0.9682
	4	2	0	0.9824	1	1	0.9967	1	0	0.9824	1	1	0.9862
	6	2	0	0.9959	1	0	0.9759	1	0	0.9959	1	0	0.9526
	8	2	0	0.9986	1	0	0.9912	1	0	0.9986	1	0	0.9824
	10	2	0	0.9994	1	0	0.9960	1	0	0.9994	1	0	0.9921
	12	2	0	0.9997	1	0	0.9979	1	0	0.9997	1	0	0.9959
0.10	2	8	2	0.9627	3	4	0.9632	4	2	0.9627	2	5	0.9623
	4	4	0	0.9651	2	1	0.9862	2	0	0.9651	1	1	0.9862
	6	4	0	0.9919	1	0	0.9759	2	0	0.9919	1	0	0.9526
	8	4	0	0.9973	1	0	0.9912	2	0	0.9972	1	0	0.9824
	10	4	0	0.9988	1	0	0.9960	2	0	0.9988	1	0	0.9921
	12	4	0	0.9994	1	0	0.9979	2	0	0.9994	1	0	0.9959
0.05	2	12	3	0.9752	4	5	0.9623	6	3	0.9752	2	5	0.9623
	4	5	0	0.9565	2	1	0.9862	4	1	0.9976	1	1	0.9862
	6	5	0	0.9898	1	0	0.9759	3	0	0.9878	1	0	0.9526
	8	5	0	0.9965	1	0	0.9912	3	0	0.9958	1	0	0.9824
	10	5	0	0.9985	1	0	0.9960	3	0	0.9982	1	0	0.9921
	12	5	0	0.9993	1	0	0.9979	3	0	0.9991	1	0	0.9959
0.01	2	17	4	0.9793	5	6	0.9633	9	4	0.9743	3	7	0.9653
	4	10	1	0.9963	3	1	0.9696	5	1	0.9963	2	2	0.9944
	6	7	0	0.9858	2	0	0.9526	4	0	0.9838	1	0	0.9526
	8	7	0	0.9951	2	0	0.9824	4	0	0.9945	1	0	0.9824
	10	7	0	0.9979	2	0	0.9921	4	0	0.9976	1	0	0.9921
	12	7	0	0.9989	2	0	0.99593	4	0	0.9988	1	0	0.9959

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